PAN-PACIFIC ENTOMOLOGIST
62(4), 1986, pp. 344–349

Response of *Plagithmysus bilineatus* Sharp (Coleoptera: Cerambycidae) to Healthy and Stressed Ohia Trees

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Abstract.—The attraction of both male and female *Plagithmysus bilineatus* Sharp beetles to stressed ohia (*Metrosideros polymorpha* Gaudichaud) trees was studied on the island of Hawaii in 1979 and 1980. Ohia trunks were severed to determine if stressed ohia were more attractive to *P. bilineatus* than were non-severed trees. Beetles initially were attracted to severed trees before they demonstrated any external signs of stress. There was no host attraction or oviposition response to control trees. The number of beetle captures did not differ significantly between the upper and lower trap bands of stressed trees, the number of adult captures and subsequent larval infestations were not correlated. When adults were caged on severed and nonsevered trees, however, severed trees had a significantly greater abundance and survival of larvae.

The decline of ohia lehua (*Metrosideros polymorpha* Gaud., Myrtaceae) on the island of Hawaii intensified between 1954 and 1972 and now covers 49,762 ha (122,912 acres) of ohia-koa forested land on the eastern slopes of Mauna Loa and Mauna Kea (Petteys et al., 1975; Hodges et al., 1986). These decline areas appear as even-aged ohia forests with definite boundaries between dead and healthy trees. This boundary corresponds to distinct types of lava flows with obvious differences in elevation and drainage. Sites with trees declining in vigor are characterized by very moist soil habitats found on poorly drained pahoehoe or 'a'a lava (Jacobi, 1983).

The native, host-specific, cerambycid beetle (*Plagithmysus bilineatus* Sharp) has often been found associated with tree mortality or reduced tree vigor in declining ohia stands (Papp et al., 1979). Although several workers have reported the association of *P. bilineatus* with ohia trees in poor vigor (Swezey, 1954; Papp et al., 1979; Papp and Samuelson, 1981), definitive studies have not been conducted to demonstrate when beetle visitation (oviposition) takes place and what effect stressed trees have on survival of larvae. Adult beetles have repeatedly been observed mating and ovipositing on felled trees. Larvae have been recovered from felled and standing stressed trees. On occasion, larvae have been found in apparently healthy trees, and late-stage larvae have completed their development as implants in healthy trees (Papp and Samuelson, 1981).

We studied *P. bilineatus* on the island of Hawaii to determine: (a) its attraction to severed hosts; (b) when this attraction takes place; and (c) the association between adults captured on boles and subsequent larval development in the boles. The hypothesis was that, given the choice, *P. bilineatus* will use trees already under stress from a complex of undetermined edaphic or climatic factors.

METHODS

The study was conducted in a presumably even-aged ohia stand, at 1260 m elevation on the northeast flank of Mauna Loa on the island of Hawaii. The trees, of unknown age (lava flow was 125 years old), averaged 6 m in height and 9 cm in diameter. Trees were randomly selected—3 pairs in 1979 and 15 pairs in 1980—from a stand of apparently vigorous and healthy trees. Half of the sample trees from both years were braced with wire and turnbuckles and severed within 10 cm of the roots. The saw kerf was sealed with Tree Seal® and all traces of sawdust removed.[1] This procedure, similar to Heikkenen's (1977), maintained the tree's vertical position, provided a known time for the onset of stress, and prevented emission of potentially attractive chemicals from the wound. The other trees were designated as controls and left uncut. To trap adult beetles, two tanglefoot bands, 8-cm wide, encircled the trunk of each sample tree 1 and 2 m above the ground. A weather station was established in the study area to record hourly changes in temperature and rainfall.

Each tree was checked three times weekly for the number of adult beetles caught in the trap bands. During each visit, adult beetles were removed from the tanglefoot to prevent recounting. After 136 days, all trees were lowered to the ground and dissected. Larvae feeding in the cambium were counted. Analysis of variance or regression was used to test significance and functional relationships between variables.

Four additional healthy trees, randomly selected in 1980, were used with caged adults to determine oviposition and larval survival in healthy and severed trees. Two of these trees were braced and severed, the other two trees were controls. A 30 cm × 45 cm screen cage was constructed and fitted to the trunk of each tree. Six pairs of beetles were placed in each cage along with a sugar-water solution. After 35 days, that portion of bark under the cages was examined, the trees were debarked, and beetle larvae were counted.

RESULTS

Trees began to wilt and show discoloration of the foliage 5 days after severing. Within an average of 10.3 days, crown coloration progressed from green to brown without turning yellow. Both male and female adult beetles were initially attracted to the severed ohia trees before any visual detection of wilting. The *P. bilineatus* adults were first captured 4 days after the trees were cut. Although beetle captures continued on severed trees for the study duration, most were captured during the first 60 days.

The time lag betwen severing of the trunk and initial capture differed between 1979 and 1980 (Fig. 1). In 1979, 50% of the 41 responding beetles were captured within 14 days; whereas, in 1980, 50% of the 78 responding beetles were captured

[1] Trade name is mentioned only for information. No endorsement by the U.S. Department of Agriculture is implied.

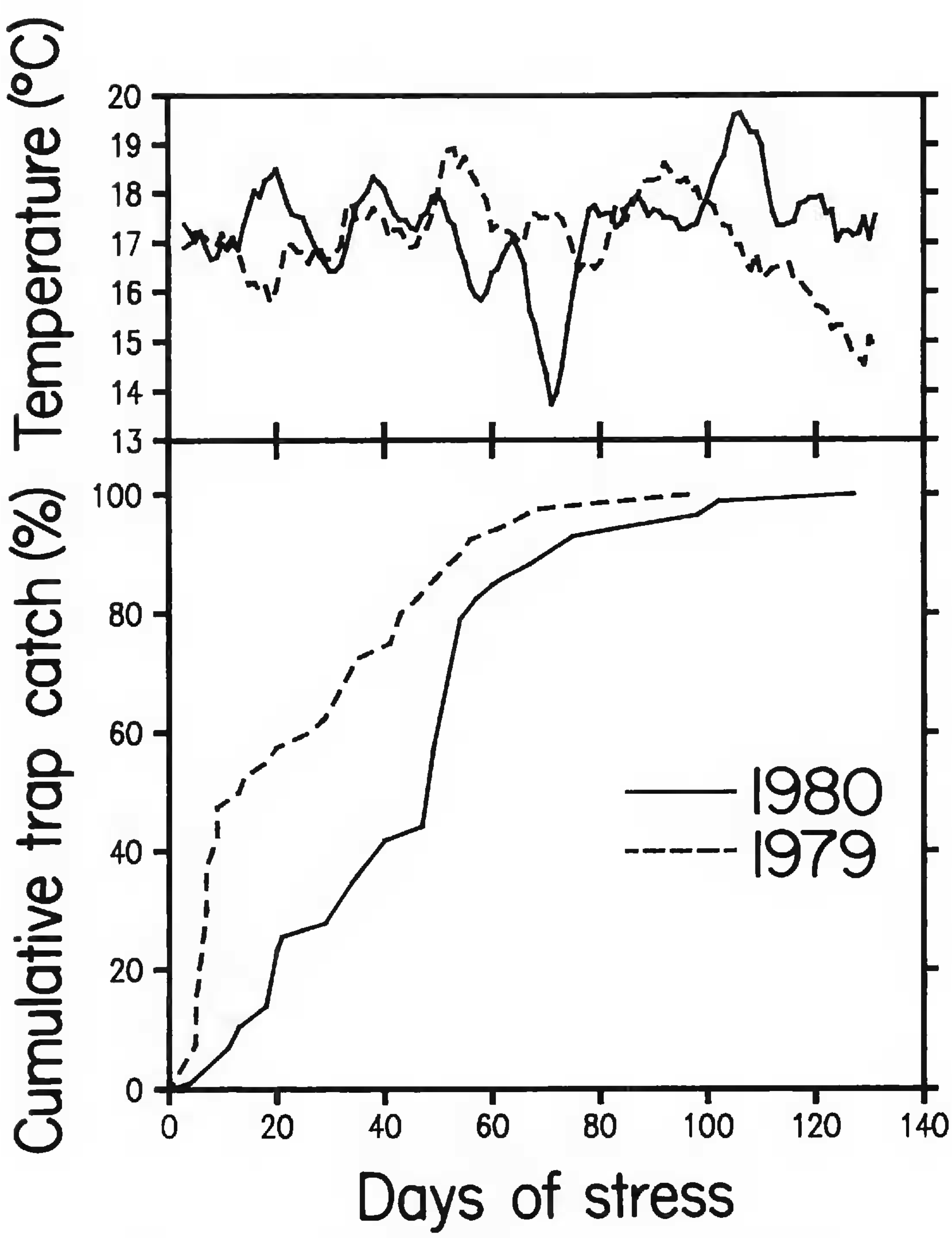

Figure 1. Capture of adult *Plagithmysus bilineatus* beetles on severed ohia trees in 1979 and 1980.

after a lapse of 46 days. No evidence of attraction to nonsevered trees was observed. Dissection of severed trees, however, revealed larvae. No larval infestation was found in nonsevered trees in either year.

Most adults were captured when it was sunny with a combination of average daily temperatures greater than 17.5°C and maximum temperatures above 21.1°C and no precipitation (Fig. 2). However, 17% of adult beetles were captured when daily precipitation was greater than 8.6 mm and the average temperature was below 17.0°C.

During the two field seasons, adults were captured on both the upper and lower tanglefoot bands on treatment trees; none were captured on the control trees. There was no significant difference ($P > 0.05$) in adult counts on the upper and lower tanglefoot bands of treatment trees, and no significant correlation between number of adults captured and the abundance of larvae. But the distribution of larvae in the tree differed significantly ($P < 0.05$). The mean difference of larvae between the top and bottom halves of trees was $\bar{X}_1 - \bar{X}_2 = 11.7$. The 95% confidence interval for this mean difference is given by $L_1 = 0.68$ and $L_2 = 22.79$. However, a positive correlation, expressed as $\hat{Y} = 8.92 + 1.23X$ ($r = 0.9124$, SE =

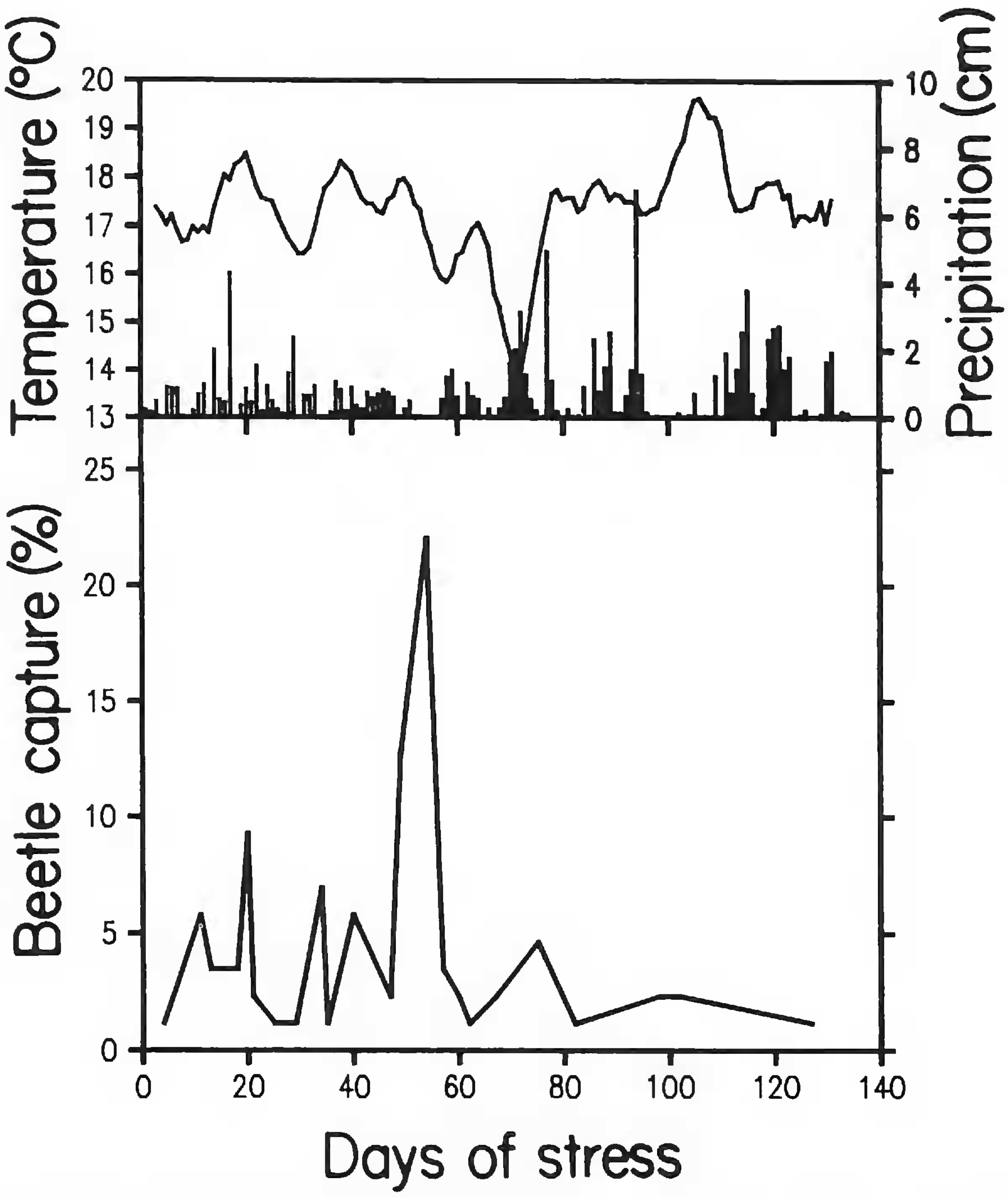

Figure 2. Percent of adult beetles captured on severed ohia trees together with a 3-day running average of temperature and precipitation (bars) in 1980.

10.1419), was found between the number of larvae in the upper half of the tree and total larvae in the entire tree. The estimating equation explained 83% of the variation in this relationship, with an estimate of 42.1 (SE = 2.62) total larvae for 27 larvae sampled in the upper half of the tree. This standard error of estimate suggests that the regression is an effective estimate of total larvae in a stressed tree by counting larvae in its top half.

Larval abundance and mortality differed significantly ($P < 0.05$) between severed and control trees with caged adults. The proportion of larvae in severed hosts was 47% greater than that in control trees ($\bar{X}_{Y_1-Y_2} = 46.5$, SE = 8.7321). The proportion of dead larvae was 75% greater in control trees ($\bar{X}_{Y_1-Y_2} = 75.29$, SE = 4.7241). The bark beneath the cages on the control trees had a total of 29 larvae. Twenty-six larvae died after tunneling 2 to 5 cm in the bark and cambium. The 3 surviving larvae averaged 4.0 mm in length. The 48 live larvae from galleries originating in bark sections beneath cages from the severed trees averaged 16 mm in length and produced an average gallery length of 39 cm. An additional 66 live larvae were recovered from galleries initiated beyond the caged portion of the severed trees, while none were found beyond the caged portion of the healthy trees.

Discussion

Both bark beetles and ambrosia beetles show an attraction response to their host plants. Water stress in Douglas-fir caused anaerobic respiration and a release of volatiles that induced the "primary attraction" of the striped ambrosia beetle *Trypodendron lineatum* (Oliver) (Graham, 1968). Similarly, *P. bilineatus* initially responded to severed trees before any visual evidence of stress was detected. The strong preference of this beetle for the severed rather than nonsevered ohia trees in this study suggests that this cerambycid was attracted to stimuli (presumably volatiles) produced by physiological changes in the host associated with extreme water stress.

The initial response of adult beetles to standing stressed ohia trees (as defined in this study) was relatively slow compared with beetle response to open wounds. In this study beetles responded after 4 days; whereas, beetles can respond to exposed wounds on a tree within 5½ hours (Papp and Samuelson, 1981).

Abrupt physiological changes in ohia, which include alterations in the sugar and amino acids, may benefit the survival of first stadium larvae (Baldwin, 1934; Mittler, 1958). Papp et al. (1979) found that beetle attacks increased as the tree crown deteriorated, but larval survival did not correlate with host condition. However, our data suggest host physiology (condition) is related to survival. Larval survival increased from 10% for healthy trees to 83% for severed trees. Therefore, adult preference for host material may ensure a measure of success by first stadium larvae.

We found that weather is significant in determining *P. bilineatus* response. Dry, sunny conditions were optimal for beetle activity. During the first month of the experiment, capture of adults was nearly ensured in favorable weather; however, we also captured adults in temperatures below 17.0°C. This is lower than any previously recorded temperature for adult flight (Papp and Samuelson, 1981) and indicates more activity during cool, wet days than was previously suspected. Differences in weather in 1979 and 1980 could account for some of the 32-day difference in reaching 50% accumulative trap catch on severed trees. A slightly different temperature and moisture regime occurred between the 2 years.

The results suggest that *P. bilineatus* beetles prefer trees that presumably produce a primary attractant under induced stressed conditions. This hypothesis of primary attraction may explain the high incidence of beetles in unhealthy trees associated with progressive stages of wetland dieback on the northeast slope of Mauna Loa (Papp et al., 1979). Beetles seldom attack vigorous trees growing adjacent to dieback boundaries on healthy sites. Water-stressed trees attract beetles, provide aggregation sites for mating and oviposition, and provide host conditions favorable for increased survival of larvae. What actually predisposes apparently healthy ohia trees to beetle attack is still unknown.

Acknowledgments

We are indebted to the Hawaii Division of Forestry and Wildlife, for access to the study site. We thank Drs. Charles S. Hodges, Jack Fujii, G. Albert Samuelson and William D. Bedard for their reviews of earlier drafts of the manuscript.

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